

4. CCT Program Accomplishments

Introduction

The CCT Program's continued success is exemplified as demonstrated by the following demonstrations completing operation in Fiscal Year 1999:

- Blast Furnace Granular-Coal Injection System Demonstration, and
- Micronized Coal Reburning Demonstration for NO_x Control.

These completed projects, along with the other 38 active and completed projects, are producing a wealth of knowledge on clean coal technologies.

The success of the CCT Program ultimately will be measured by the contribution the technologies make to the resolution of energy, economic, and environmental issues. These contributions can only be achieved if the public and private sectors understand that clean coal technologies can increase the efficiency of energy use and enhance environmental quality at costs that are competitive with alternative energy options.

The CCT Program has continued efforts to define and understand the potential domestic and international markets for clean coal technologies. Domestically, this activity requires a continuing dialogue with electric utility executives, public utility commissioners, and financial institutions. Also required are analyses of the effect that regional electric capacity requirements, environmental compliance strategies, and electric utility restructuring have on the demand for clean coal technologies. Internationally, activities include participating in international conferences and workshops, furnishing information on clean coal technologies, and

providing technical support to trade agencies, trade missions, and financial organizations.

Throughout the 1999 fiscal year, the CCT Program staff participated in over 16 domestic and international events involving users and vendors of clean coal technologies, regulators, financiers, environmental groups, and other public and private institutions. Included was the Seventh Clean Coal Technology Conference, held in Knoxville, Tennessee and attended by 230 participants from 12 countries. Four issues of the *Clean Coal Today* newsletter were published in the same period, along with the fourth annual edition of the *Clean Coal Today Index*, which cross-references all articles published in the newsletter. A new series of reports, 12-page *Project Performance Summary* documents, were issued for 10 of the completed CCT Program projects. Also, four *Clean Coal Technology* topical reports were issued during the fiscal year. The DOE also continued expanded coverage of the program by publishing the *Clean Coal Technology Demonstration Program: Update 1998*, and the mid-year update of project fact sheets, *Clean Coal Technology Demonstration Program: Project Fact Sheets 1999*.

Subsequent to the end of fiscal year 1999, but prior to publication of this report, the cooperative agreement for two demonstration projects expired—NOXSO Corporation and Custom Coals International are in bankruptcy and were not able to restructure and continue work under the CCT Program. Information on NOXSO Corporation's Commercial Demonstration of the NOXSO SO₂/NO_x Removal Flue Gas Cleanup System and Custom Coals International's Self-Scrubbing Coal™: An Integrated Approach projects are included in this report because there is data that read-



ers may find beneficial. Furthermore, this report is based on the status as of September 30, 1999 and the expiration of these cooperative agreements occurred after that date. These two projects will not be included in future reports.

Marketplace Commitment

Reflecting CCT Program commercialization goals, the majority of the projects involve demonstrations at commercial scale, providing the opportunity for the participants to continue operation of the demonstrated technologies as part of their strategy to comply with the CAAA.

With government serving as a risk-sharing partner, industry funding has been leveraged to:

- Create jobs,
- Improve the environment,
- Reduce the cost of compliance with environmental regulations,
- Reduce the cost of electricity generation,

▼ SO₂ control technologies: AirPol (left), CT-121 (center), and LIFAC (right).



- Improve power generation efficiencies, and
- Position U.S.-based industry to export innovative services and equipment.

Reflecting the marketplace commitment, the CCT projects are organized within four major product lines—environmental control devices, advanced electric power generation, coal processing for clean fuels, and industrial applications. Thus, the CCT Program can be viewed from a market perspective. This section of the *Program Update* highlights some of the program and project accomplishments to date along with commercialization successes by market sector.

Environmental Control Devices

All but 2 of the 19 environmental control device projects have now completed operations. The completed demonstrations proved commercial viability of a suite of cost-effective SO₂ and NO_x control options for the full range of coal-fired boiler types. Risk was significantly mitigated in successfully applying the technologies commercially because of the extensive databases and attendant predictive models developed through the demonstrations. Also, projects were lever-

aged to provide input in formulating NO_x control requirements under the CAAA and to evaluate the impact of emerging issues, such as air toxics, on the existing boiler population and control options. Extensive air toxics testing was performed in conjunction with 10 of the environmental control projects. To a great extent, the technologies were retained for commercial service at the demonstration sites and many technology suppliers have realized commercial sales.

SO₂ Control Technologies. All five SO₂ control technology demonstrations have completed operations, evaluating three basic approaches to address the diverse coal-fired boiler population: (1) sorbent injection, (2) gas-suspension absorption, and (3) advanced flue gas desulfurization.

- Two low-capital cost **sorbent injection** systems, sponsored by LIFAC–North America and Bechtel Corporation, demonstrated SO₂ capture efficiencies in the range of 50 to 70 percent. These systems hold particular promise for the older, smaller units, particularly those with space constraints.
- A moderate-capital cost **gas-suspension-absorption** system, sponsored by AirPol, Inc., demonstrated SO₂ capture efficiencies in the range of 60 to 90 percent. The system has particular applicability to the small- to mid-range units with some space limitations.
- Two **advanced flue gas desulfurization** (AFGD) systems, sponsored by Pure Air on the Lake, L.P. and Southern Company Services, having somewhat higher capital costs than the other approaches, demonstrated SO₂ capture efficiencies in the range of 90 to 95 percent. These systems are primarily applicable to the larger, newer units that have space available.

The AFGD projects redefined the state-of-the-art in scrubber technology by proving that a single absorber module of advanced design could process large volumes of flue gas and provide the required availability and reliability. This single module design, without the usual spares, combined with integration of functions within the absorber module and use of high throughput designs, nearly halved capital cost and space requirements. The AFGD testing also established that wallboard-grade gypsum could be produced in lieu of solid waste; wastewater discharge could be eliminated; and, by mitigating corrosion, fiberglass-reinforced-plastic fabrication could eliminate process steps (e.g., prequenching for chloride removal and flue gas reheat).

The AFGD demonstration by Southern Company Services using Chiyoda CT-121 showed that the system could significantly enhance particulate control. Pure Air on the Lake, L.P., introduced an innovative business concept whereby the company builds, owns, and operates scrubbers as a contracted service to a utility. The arrangement relieves utilities of the burden of ownership and operation.

Commercialization successes to date for the SO₂ control technologies are summarized in Exhibit 4-1.

NO_x Control Technology. Six of the seven NO_x control technology demonstrations have successfully completed operations. Testing was conducted on the four major boiler types (wall-fired, tangentially-fired, cyclone-fired, and cell-burner boilers), representing over 90 percent of the coal-fired boiler population; however, applicability extends to all boiler types.

Typically, NO_x emission reductions achieved for the various approaches were:

- Low-NO_x burners and OFA: 45 to 68 percent
- Reburning systems: 50 to 67 percent

- SNCR systems: 30 to 50 percent
- SCR systems: 80 to 90+ percent
- Advanced controls: 10 to 15 percent

The database developed during Southern Company Services' evaluation of NO_x control on wall-fired and tangentially-fired boilers at Plant Smith and Plant Hammond, respectively, was used by EPA in formulating NO_x provisions under the CAAA. ABB Combustion Engineering's LNCFS™ proved effective in demonstration for tangentially-fired boilers and realized commercial acceptance, as did Foster Wheeler's Controlled Flow/Split Flame and Babcock & Wilcox's DRB-XCL® low-NO_x burners for wall-fired boilers. The Babcock & Wilcox Company's low-NO_x cell burner, LNCB®, provided an effective low-cost plug-in NO_x control system for cell-burner boilers, which are known for their inherently high NO_x emissions.

Integration of neural-network systems into digital boiler controls, such as the Generic NO_x Control Intelligence System (GNOCIS) installed at Plant Hammond, demonstrated effective optimization of parameters for NO_x control and boiler performance under load-following operations.

The Babcock & Wilcox Company's coal reburning technology proved not only to be an effective way to control NO_x on cyclone boilers, but a means to avoid derating cyclone boilers when switching to low-sulfur, low-rank western coals. Energy and Environmental Research Corporation's use of gas reburning, applicable to all boiler types, introduced an alternative to SCR for high NO_x emission reduction particularly when used with low-NO_x burners.

In another project, comparative analyses were conducted on a range of SCR catalysts operated on high-sulfur U.S. coals, providing needed insight on the environmental and economic performance potential of

SCR. Other SCR systems and selective non-catalytic reduction (SNCR) systems were demonstrated in conjunction with combined SO₂/NO_x control technologies.

Commercialization successes to date for the NO_x control technologies are summarized in Exhibit 4-2.

Combined SO₂/NO_x Control Technologies.

Six of the seven combined SO₂/NO_x control technology demonstrations have successfully completed operations. The demonstrations evaluated a multiplicity of complementary and synergistic control methods to achieve cost-effective SO₂ and NO_x emissions reductions.

SNOX™, a catalytic process developed by Haldor Topsoe a/s, consistently achieved 95 and 94 percent SO₂ and NO_x control, respectively. The process also demonstrated excellent particulate control, while producing a salable by-product in lieu of solid waste.

In a project sponsored by Public Service Company of Colorado, complementary use of low-NO_x burners with SNCR resulted in NO_x emission reductions of greater than 80 percent. SNCR interacted synergistically with sorbent injection to reduce ammonia slip and NO_x emissions. Sodium-based sorbent injection achieved 70 percent SO₂ removal at high sorbent utilization rates.

New York State Electric & Gas Corporation (NYSEG) evaluated an advanced flue gas desulfurization system, the S-H-U scrubber process. The S-H-U process, an advanced formic acid-enhanced wet limestone scrubbing process, demonstrated a 98 percent SO₂ capture efficiency. In conjunction with the S-H-U process, NYSEG also evaluated micronized coal as a reburn fuel using close-coupled reburning techniques and deep staged combustion incorporated into ABB Combustion Engineering, Inc.'s LNCFS™ burners.

Exhibit 4-1

Commercial Successes—SO₂ Control Technology

Project	Commercial Use
10-MWe Demonstration of Gas Suspension Absorption (AirPol, Inc.)	Sold domestically and internationally. GSA market entry was significantly enhanced with the sale of a 50-MWe unit, worth \$10 million, to the city of Hamilton, Ohio subsidized by the Ohio Coal Development Office. A sale worth \$1.3 million has been made to the U.S. Army for hazardous waste disposal. A GSA system has been sold to a Swedish iron ore sinter plant. Sales to Taiwan, Indonesia, and India have a combined value of \$20 million. Furthermore, Taiwan contracted for technical assistance and proprietary equipment valued at \$1.0 million.
Confined Zone Dispersion Flue Gas Desulfurization Demonstration (Bechtel Corporation)	No sales reported. CZD/FGD can be used to retrofit existing plants or for new installations at a cost of about one-tenth that of a commercial wet scrubber.
LIFAC Sorbent Injection Desulfurization Demonstration Project (LIFAC–North America)	Sold domestically and internationally. There are 10 full-scale LIFAC units in operation in Canada, China, Finland, Russia, and the United States. The LIFAC system at Richmond Power & Light is the first to be applied to a power plant using high-sulfur (2.0-2.9%) coal. The LIFAC system has been retained for commercial use by Richmond Power & Light at Whitewater Valley Station, Unit No. 2.
Advanced Flue Gas Desulfurization Demonstration Project (Pure Air on the Lake, L.P.)	No sales reported. The AFGD continues in commercial service at Northern Indiana Public Service Company's Bailly Generating Station. Gypsum produced by the PowerChip® process is being sold commercially.
Demonstration of Innovative Applications of Technology for the CT-121 FGD Process (Southern Company Services, Inc.)	Sold internationally. Plant Yates continues to operate with the CT-121 scrubber as an integral part of the site's CAAA compliance strategy. Since the CCT Program demonstration, over 8,200 MWe equivalent of CT-121 FGD capacity has been sold to 16 customers in 7 countries.

Exhibit 4-2

Commercial Successes—NO_x Control Technology

Project	Commercial Use
Micronized Coal Reburning Demonstration for NO _x Control (New York State Electric & Gas Corporation)	No sales reported. Technology retained for commercial use at Kodak Power Plant.
Demonstration of Coal Reburning for Cyclone Boiler NO _x Control (The Babcock & Wilcox Company)	No sales reported. Technology retained for commercial use at Wisconsin Power and Light Company's Nelson Dewy Station.
Full-Scale Demonstration of Low-NO _x Cell Burner Retrofit (The Babcock & Wilcox Company)	Sold domestically. Dayton Power & Light has retained the LNCB® for use in commercial service. Seven commercial contracts have been awarded for 172 burners, valued at \$27 million. The LNCB® technology has already been installed on more than 4,900 MWe of capacity.
Evaluation of Gas Reburning and Low-NO _x Burners on a Wall-Fired Boiler (Energy and Environmental Research Corporation)	Sold domestically and internationally. Public Service Company of Colorado, the host utility, decided to retain the low-NO _x burners and the gas-reburning system for immediate use; however, a restoration was required to remove the flue gas recirculation system. Energy and Environmental Research Corporation has been awarded two contracts to provide gas reburning systems for cyclone coal-fired boilers: TVA's Allen Unit 1 (a 330-MWe unit) as well as Baltimore Gas & Electric's C. P. Crane Units 1 and 2 (similar 200-MWe units). The technology is also installed at Ladyzkin State Power Station in Ladyzkin, Ukraine.
Demonstration of Selective Catalytic Reduction Technology for the Control of NO _x Emissions from High-Sulfur, Coal-Fired Boilers (Southern Company Services, Inc.)	No sales reported. SCR has realized commercial acceptance abroad. The demonstration tests established SCR as a viable U.S. compliance option and aided utilities in developing the most cost-effective site-specific applications of SCR.
180-MWe Demonstration of Advanced Tangentially-Fired Combustion Techniques for the Reduction of NO _x Emissions from Coal-Fired Boilers (Southern Company Services, Inc.)	Sold domestically and internationally. LNCFS™ has been retained at the host site for commercial use. ABB Combustion Engineering has modified 116 tangentially-fired boilers, representing over 25,000 MWe, with LNCFS™ and derivative TFS 2000™ burners.
Demonstration of Advanced Combustion Techniques for a Wall-Fired Boiler (Southern Company Services, Inc.)	Sold domestically and internationally. The host has retained the technologies for commercial use. Foster Wheeler has equipped 86 boilers (51 domestic and 35 international) with low-NO _x burner technology—a total of 1,800 burners representing over 30,000 MWe capacity valued at \$35 million. Twenty-six commercial installations of GNOCIS, the associated AI control system, are underway or planned. This represents over 12,000 MWe of capacity. In a strict sense, this project has not been completed; it has been extended to apply GNOCIS to other pieces of plant equipment, which may increase its commercial potential.

DHR Technologies supplied a plant optimization control system known as the Plant Emission Optimization Advisor or PEOA™, which has been sold to a number of users in the power industry.

The Babcock & Wilcox Company's SO_x-NO_x-Rox Box™, an integration of a newly developed high-temperature fabric-filter bag (for baghouse installations) with SCR and sorbent injection, proved to be an easily installed, highly efficient control system for SO₂, NO_x, and particulates. Typical performance was 80 percent SO₂ removal, 90 percent NO_x removal, and 99.9 percent particulate removal.

Limestone injection multistage burner (LIMB) and coolside demonstrations proved that sorbent injection methods could achieve up to 70 percent SO₂ reduction. The Babcock & Wilcox DRB-XCL® advanced low-NO_x burners reduced NO_x emissions by 45 percent.

Energy and Environmental Research Corporation's demonstration of gas reburning and sorbent injection showed that: (1) NO_x reductions greater than 60 percent could be achieved with only 13 percent natural gas heat input, and (2) SO₂ removal of over 55 percent could be achieved by using special sorbents. NOXSO Corporation's demonstration of a dry, regenerable flue gas cleanup process is designed to remove 98 percent of the SO₂ and 75 percent of the NO_x from a coal-fired boiler's flue gas.

Commercialization successes to date for the combined SO₂ and NO_x control technologies are summarized in Exhibit 4-3.

Advanced Electric Power Generation

Pollution control was the priority early in the CCT Program. This program emphasis included technologies that could effectively repower aging plants faced with the need to both control emissions and respond to

growing power demands. Repowering is an important option because existing power generation sites have significant value and warrant investment because the infrastructure is in place and siting new plants represents a major undertaking. This recognition led to award early on of three key repowering projects—two ACFB projects and a PFBC project.

As the CCT Program unfolded, a number of energy and environmental issues combined to change the emphasis toward seeking highly-efficient, very low-emission power generation technologies for both repowering and new power generation. This emphasis was deemed essential to enable coal to fulfill its projected contribution to the nation's energy mix well into the 21st century. Environmental issues included a growing concern over greenhouse gas emissions, capping of SO₂ emissions, increasing attention to NO_x in ozone nonattainment areas, and recognizing fine particulate emissions (respirable particulates) as a particular health threat. These issues prompted follow-on projects in PFBC, initiation of projects in IGCC, and projects in advanced combustion and heat engines.

Fluidized-Bed Combustion. The Tri-State Generation and Transmission Association, Inc.'s Nucla Station repowering project provided the database and operating experience requisite to making ACFB a commercial technology option at utility scale. At 110 MWe, the Nucla ACFB unit was more than 40 percent larger than any other ACFB at that time. Up to 95 percent SO₂ removal was achieved during the 15,700 hours of demonstration, and NO_x emissions averaged a very low 0.18 lb/10⁶ Btu. The thrust of this effort was to fully evaluate the environmental, operational, and economic performance of ACFB. As a result, the most comprehensive database on ACFB technology available to date was developed. Based on this knowledge, commercial units were offered and built.

While the Nucla project established commercial acceptance of ACFB at moderate utility capacities, a second CCT demonstration project, located in Jacksonville, Florida, is carrying on where Nucla left off. JEA will build a 300-MWe plant, which will have the distinction of being the largest ACFB in the world, as well as one of the cleanest.

Today, every major U.S. boiler manufacturer offers an ACFB in its product line. There are now more than 120 fluidized-bed combustion boilers of varying capacities operating in the United States, and the technology has made significant market penetration abroad.

Through the Ohio Power Company's repowering of the Tidd Plant (70 MWe), the potential of PFBC as a highly efficient, very low pollutant emission technology was established and the foundation was laid for commercialization. The PFBC system constructed was the first utility-scale system in the United States. Efforts were focused on fully evaluating the performance potential. Over 11,444 hours of operation, the technology successfully demonstrated SO₂ removal efficiencies up to 95 percent with very high sorbent utilization (calcium-to-sulfur molar ratio of 1.5), and NO_x emissions in the range of 0.15 to 0.33 lb/10⁶ Btu.

The Tidd Plant PFBC was one of the first generation 70-MWe P200 units installed in the early 1990s. Others were built and operated in Sweden, Spain, and Japan. ABB Carbon, the technology supplier, uses a "bubbling" fluidized-bed design, which is characterized by low fluidization velocities and use of an in-bed heat exchanger. The first 360-MWe P800 PFBC is being built in Japan and is scheduled for operation in 1999. And, a "second generation" P200 PFBC with freeboard-firing is operating in Cottbus, Germany. A number of other ABB Carbon PFBC projects are under

Exhibit 4-3

Commercial Successes—Combined SO₂/NO_x Control Technology

Project	Commercial Use
SNOX™ Flue Gas Cleaning Demonstration Project (ABB Environmental Systems)	International use. The host utility, Ohio Edison, is retaining the SNOX™ technology as a permanent part of the pollution control system at Niles Station to help meet its overall SO ₂ and NO _x reduction goals. Commercial SNOX™ plants are also operating in Denmark and Sicily. In Denmark, a 305-MWe plant has operated since August 1991. The boiler at this plant burns coals from various suppliers around the world, including the United States; the coals contain 0.5-3.0% sulfur. The plant in Sicily, in operation since March 1991, has a capacity of about 30 MWe and fires petroleum coke.
LIMB Demonstration Project Extension and Coolside Demonstration (McDermott Technology, Inc.)	Sold domestically and internationally. LIMB has been sold to an independent power plant in Canada. Babcock & Wilcox has signed contracts for 124 units for DRB-XCL® low-NO _x burners, representing 2,428 burners for 31,467 MWe of capacity. The low-NO _x burners have an estimated value of \$240 million.
SO _x -NO _x -Rox Box™ Flue Gas Cleanup Demonstration Project (The Babcock & Wilcox Company)	No sales reported. Commercialization of the technology is expected to develop with an initial larger scale application equivalent to 50-100 MWe. The focus of marketing efforts is being tailored to match the specific needs of potential industrial, utility, and independent power producers for both retrofit and new plant construction. SNRB™ is a flexible technology that can be tailored to maximize control of SO ₂ , NO _x , particulate, or combined emissions to meet current performance requirements while providing flexibility to address future needs.
Enhancing the Use of Coals by Gas Reburning and Sorbent Injection (Energy and Environmental Research Corporation)	No sales reported. Illinois Power has retained the gas-reburning system and City Water, Light & Power has retained the full technology for commercial use. (See Evaluation of Gas Reburning and Low-NO _x Burner on a Wall-Fired Boiler project for a complete understanding of commercial success of the technology.)
Milliken Clean Coal Technology Demonstration Project (New York State Electric & Gas Corporation)	Sold domestically. Six modules of DHR Technologies' Plant Emissions Optimization Advisor, with an estimated value of \$210,000, have been sold. A U.S. company, SHN, has been established to market the S-H-U scrubber. SHN is pursuing an advanced flue gas desulfurization bid for a Pennsylvania site. ABB Combustion Engineering has modified 116 units representing over 25,000 MWe with LNCFS™ or its derivative TFS 2000™.
Integrated Dry NO _x /SO ₂ Emissions Control System (Public Service Company of Colorado)	Sold domestically. The technology was retained by Public Service Company of Colorado for commercial service at its Arapahoe Station. The Babcock & Wilcox DRB-XCL® burner that was demonstrated has realized sales of 2,428 burners, representing 31,467 MWe. The burners are valued at \$240 million.

consideration in China, South Korea, the United Kingdom, Italy, and Israel.

Two ongoing interrelated projects, McIntosh 4A and McIntosh 4B, will demonstrate PCFB at utility scale. PCFB uses a higher fluidization velocity than bubbling-bed systems, which entrains the bed material. Bed material is separated from the flue gas by cyclones and recirculated to the combustor. The economizer, which captures heat from the flue gas, is downstream of the cyclones. McIntosh 4A will evaluate a 137-MWe first generation PCFB configuration using Foster Wheeler technology. McIntosh 4B will demonstrate a second generation system by integrating a small coal gasifier (pyrolyzer) to fuel the gas turbine "topping cycle," thereby adding 103 MWe capacity. The second generation PCFB has the potential to significantly improve the efficiency of pressurized fluidized-bed systems by increasing power generation from the gas turbine, which is more efficient than the steam bottom cycle.

Integrated Gasification Combined-Cycle. Three of four IGCC projects are in operation under the CCT Program. They represent a diversity of gasifier types, cleanup systems, and applications. PSI Energy's 262-MWe Wabash River Coal Gasification Repowering Project began operation in November 1995 and continues in its fourth year of commercial service. The utility dispatches the unit over other coal-fired units because of its high efficiency. The unit, which is the world's largest single train IGCC, has operated on coal for over 12,400 hours and processed more than one million tons of coal. The unit has achieved monthly production levels of one trillion Btus of syngas on several occasions.

The 250-MWe Tampa Electric Integrated Gasification Combined-Cycle Project began commercial operation in September 1996 and continues to accumulate run time. The gasifier has accumulated over

15,000 hours of operation and produced over 3,500,000 MWh of electricity on syngas. Tests have included evaluation of various coal types on system performance.

The Sierra Pacific Power Company (SPPC) continues to make progress on its IGCC system. The 99-MWe Piñon Pine IGCC Power Project at SPPC's Tracy Station began operation on natural gas in November 1996. The GE Frame 6FA, the first of its kind in the world, performed well. The plant has undergone shakedown, and design modifications have been made. The system has achieved steady state gasifier operation for short periods through September 1999, but continues to experience difficulty with sustained operations.

The Kentucky Pioneer Energy IGCC Demonstration Project, which is in the design stage, will offer yet another gasifier design and include the testing of a fuel cell operated on syngas from the coal gasifier. This will provide valuable data for design of an integrated gasification fuel cell (IGFC) system. IGFC has the potential to achieve efficiencies greater than 60 percent.

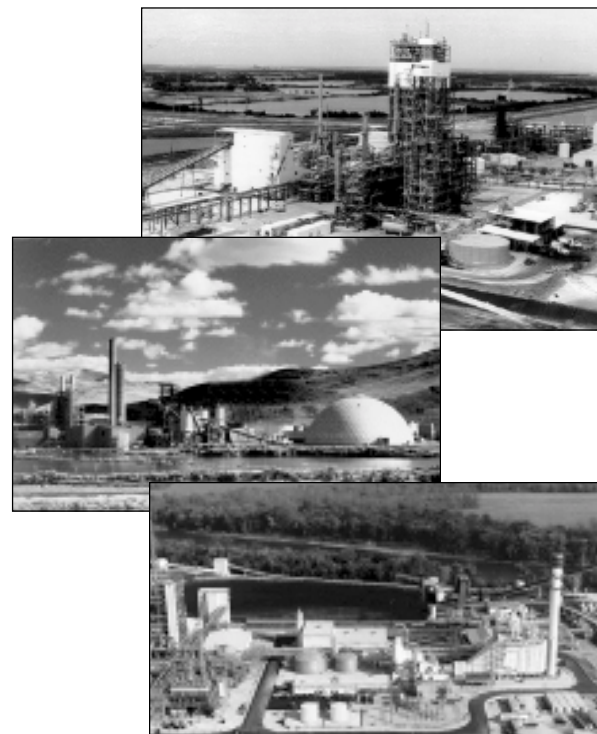
Commercial configurations resulting from the current IGCC and PFBC demonstrations will typically have efficiencies at least 20 percent greater than conventional coal-fired systems (with like CO₂ emission reductions), remove 95 to 99 percent of the SO₂, reduce NO_x emissions to levels well within NSPS, reduce particulate emissions by one-third to one-tenth that currently allowed under the CAAA, and produce salable by-products from solid residues as opposed to waste.

Advanced Combustion/Heat Engines. Two projects are demonstrating advanced combustion/heat engine technology. The Healy Clean Coal Project is demonstrating TRW's entrained (slagging) combustor combined with Babcock & Wilcox's spray-dryer

absorber using sorbent recycle. Operations commenced in January 1998. Results from environmental compliance testing showed very low emissions—0.26 lb/10⁶ Btu for NO_x, 0.01 lb/10⁶ Btu for SO₂, and 0.0047 lb/10⁶ Btu for particulates. Permit levels are 0.35 lb/10⁶ Btu for NO_x, 0.086 lb/10⁶ Btu for SO₂, and 0.03 lb/10⁶ Btu for particulates because of the plant's proximity to a national park. NSPS allows 1.2 lb/10⁶ Btu for SO₂.

The Clean Coal Diesel Demonstration Project is evaluating a heavy duty diesel engine operating on a low-rank coal-water fuel. The demonstration plant is expected to achieve 41 percent efficiency and future commercial designs are expected to reach 48 percent

▼ Three IGCC plants are in operation: Tampa Electric (top), Piñon Pine (middle), and Wabash River (bottom).



efficiency. As of September 1999, the checkout of the diesel engine was in progress.

Commercialization successes for the advanced electric power generation systems to date are summarized in Exhibit 4-4.

Coal Processing for Clean Fuels

Two of five projects in the coal processing for clean fuels category completed operations and submitted final reports. Projects in this category include physical and chemical processes that can be used to transform the abundant U.S. coal reserves into economic, environmentally compliant solid and liquid fuels and feedstocks. The solid products from coal processing are largely designed to be readily transportable; high in energy density; and low in sulfur, ash, and moisture. The liquid products are designed to be suitable as transportation and stationary power generation fuels, or as chemical feedstocks. Both solid and liquid products, and the processes that produce them, have substantial market potential both domestically and internationally.

The ENCOAL and Western SynCoal LLC projects are breaking down the barrier to using the nation's vast low-sulfur but low-energy-density western coal resources. The resultant fuels have particular application domestically for CAAA compliance and internationally for Pacific Rim energy markets.

ENCOAL's solid fuel product has an energy density of about 11,000 Btu per pound, and the sulfur content averages 0.36 percent. ENCOAL's liquid fuel product can substitute for No. 6 fuel oil or serve as a chemical feedstock. During the demonstration, over 83,500 tons of solid fuel was shipped to seven customers in six states, as well as 203 tank cars of liquid product to eight customers in seven states. Five com-

mercial feasibility studies have been completed—two for Indonesia, one for Russia, and two for U.S. projects. Permitting of a 15,000 metric ton/day commercial plant in Wyoming is nearly complete.

The Western SynCoal LLC project is demonstrating another route to producing high-quality fuel from low-rank coals. The advanced coal conversion process (ACCP) upgrades low-rank coal to produce a low-sulfur (as low as 0.3 percent sulfur) SynCoal® product having a heating value of about 12,000 Btu per pound. The Western SynCoal LLC has signed a letter of agreement to supply fuel to Montana Power's 330-MWe Colstrip Unit No. 2. Five other agreements have been signed.

The advanced physical coal-cleaning technology developed by Custom Coals International uses high-sulfur bituminous feedstocks to produce two types of compliance coal—Carefree Coal™ and Self-Scrubbing Coal™.

Air Products Liquid Phase Conversion Company, L.P., is demonstrating the LPMEOH™ process to produce methanol from coal-derived synthesis gas. The LPMEOH™ process has been developed to enhance integrated gasification combined-cycle power generation facilities by coproducing a clean-burning storable liquid fuel from coal-derived synthesis gas. The production of dimethyl ether (DME) as a mixed coproduct with methanol will also be demonstrated. Methanol and DME may be used as a low-SO₂, low-NO_x alternative liquid fuel, a feedstock for the synthesis of chemicals, or as a new oxygenate fuel additive. Since start-up, the LPMEOH™ demonstration unit has produced over 43 million gallons of methanol, all of which was accepted by Eastman Chemical Company for use in downstream chemical processing. Since restart of the unit with fresh catalyst in December

1997, availability of the unit has been greater than 99 percent and catalyst activity decline has approached 0.4 percent/day.

ABB Combustion Engineering, Inc. and CQ Inc. developed PC-based software, CQE™, to assist utilities in assessing the environmental and operational performance of their systems for the available range of coal fuels to determine the least-cost option. The CQE™ software has been distributed to over 35 utility members of EPRI and is being marketed commercially worldwide. Two U.S. utilities also have been licensed to use copies of the CQE™ stand-alone Acid Rain Advisor.



▲ The LPMEOH™ demonstration unit at Eastman Chemical Company's vast chemicals-from-coal complex in Kingsport, TN.

Exhibit 4-4

Commercial Successes—Advanced Electric Power Generation

Project	Commercial Use
Tidd PFBC Demonstration Project (The Ohio Power Company)	<p>Sold internationally. Success of the project has led Babcock & Wilcox to invest in the technology and acquire domestic licensing rights.</p> <p>Commercial ventures abroad include the following:</p> <ul style="list-style-type: none"> – Vartan in Sweden is operating two P200 units to produce 135 MWe and 224 MWt; – Escatron in Spain is operating one P200 unit producing 80 MWe; – Wakamatsu in Japan is operating one P200 unit to produce 71 MWe; – Cottbus in Germany is operating one P200 unit to produce 71 MWe and 40 MWt; – Karita in Japan operates one P800 unit to produce 360 MWe; and – Other projects under construction are in China, South Korea, U.K., and Israel.
Nucla CFB Demonstration Project (Tri-State Generation and Transmission Association, Inc.)	<p>Sold domestically and internationally. Today, every major boiler manufacturer offers an ACFB system in its product line. Since the demonstration, commercial sales of 29 units greater than 100 MWe have been realized, representing 6.2 gigawatts of capacity valued at nearly \$6 billion.</p>
Tampa Electric Integrated Gasification Combined-Cycle Project (Tampa Electric Company)	<p>Sold domestically and internationally. First greenfield IGCC unit in commercial service. Texaco, Inc., and ASEA Brown Boveri signed an agreement forming an alliance to market IGCC technology in Europe. There are currently 10 IGCC projects using a Texaco gasifier that are either planned or under construction.</p>
Wabash River Coal Gasification Repowering Project (Wabash River Coal Gasification Repowering Project Joint Venture)	<p>No sales reported. First repowered IGCC unit in commercial service and is the world's largest single train IGCC in commercial service. Preferentially dispatched over other coal-fired units is PSI Energy's system because of high efficiency.</p>
Piñon Pine IGCC Power Project (Sierra Pacific Power Company)	<p>No sales reported. Unit in initial operation preparatory to commercial service.</p>
Healy Clean Coal Project (Alaska Industrial Development and Export Authority)	<p>No sales reported. TRW offering licensing of combustor worldwide (China agreement in place). Commercial operation tests are ongoing.</p>

Commercialization successes for the coal processing technologies to date are summarized in Exhibit 4-5.

Industrial Applications

The CCT Program is addressing the environmental issues and barriers associated with coal use in industrial applications. Three of five projects have completed operations in this area.

Historically, production of steel has been dependent upon coke. Coke making, however, is an inherently large producer of hazardous air pollutants. Also, cement production often relies on coal fuel because production costs are largely driven by fuel costs. Because of its low stable price, coal is an attractive substitute for oil and gas in industrial boilers, but concerns over increased SO₂ and NO_x emissions and boiler tube fouling have impeded coal use.

Under a project with Bethlehem Steel Corporation, British Steel's blast furnace granular-coal injection (BFGCI) technology demonstrated that 40 percent of the coke can be replaced with coal injected directly into a blast furnace where emissions from coal combustion are effectively controlled in the process.

CPICOR™ Management Company L.L.C. is in the design stage of demonstrating direct iron ore reduction and smelting of iron oxides using coal in lieu of coke. This would eliminate the need for coke.

The Passamaquoddy Tribe successfully demonstrated a unique recovery scrubber that uses cement kiln dust, otherwise disposed of as waste, to remove 90 percent of the SO₂, produce fertilizer and distilled water, and convert the kiln dust to feedstock with no waste generated.

Coal Tech Corporation moved closer to commercializing a combustor for industrial boilers that slags

the ash in the combustor to prevent boiler tube fouling, controls NO_x (70 to 80 percent reduction) through staged combustion, and controls SO₂ (90 percent) with sorbent injection. ThermoChem, Inc. has completed restructuring of its project and will be demonstrating a multiple resonance tube pulse combustor design.

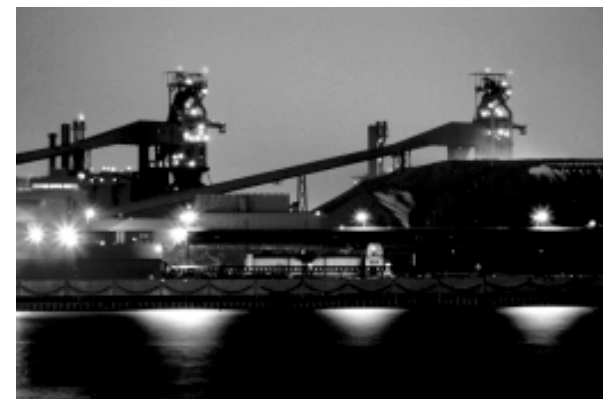
Commercialization successes for the industrial applications technologies to date are summarized in Exhibit 4-6.

Awards

The projects in the CCT Program have won numerous awards from news, professional, and non-profit organizations. A listing of those awards is contained in Exhibit 4-7.

Market Communications— Outreach

Outreach has been a hallmark of the CCT Program since its inception. It was recognized early on that commercialization of technology requires acceptance by a range of interests including: technology users; equipment manufacturers; suppliers and users of raw materials and products; financial institutions and insurance underwriters; government policy makers, legislators, and regulators; and public interest groups. Requisite to acceptance is an outreach program to provide these customers and stakeholders with both program and project information and to seek, on a continuing basis, feedback on program direction and information requirements. An ongoing outreach program has aggressively sought to disseminate key information to the full range of customers and stake-



▲ The Burns Harbor Plant was the site of the BFGCI demonstration.

holders and to obtain feedback on changing needs. The effort has recognized the need to highlight environmental, operational, and economic performance characteristics of clean coal technologies and to redesign information packages as customers and stakeholders, and their respective needs, change with the market. Specific objectives of the outreach program include the following:

- Achieving public and government awareness of advanced coal-using technologies as viable energy options;
- Providing potential technology users, both foreign and domestic, with information that is timely and relevant to their decision making process;
- Providing policy makers, legislators, and regulators with information about the advantages of clean coal technologies;
- Convincing financial institutions and insurance underwriters that clean coal technologies are viable options; and

Exhibit 4-5

Commercial Successes—Coal Processing for Clean Fuels

Project	Commercial Use
Development of the Coal Quality Expert™ (ABB Combustion Engineering, Inc. and CQ, Inc.)	Sold domestically and internationally. The Electric Power Research Institute (EPRI) owns the software and distributes it to EPRI members for their use. CQ Inc. and Black and Veatch have signed commercialization agreements that give both companies nonexclusive worldwide rights to sell user licenses and offer consulting services that include use of CQE®. More than 35 U.S. utilities and one U.K. utility have received CQE® through EPRI membership. Two modules of the Acid Rain Advisor valued at \$6,000 have been sold. It is estimated that CQE® saves U.S. utilities about \$26 million annually.
ENCOAL® Mild Coal Gasification Project (ENCOAL Corporation)	Domestic and international sales pending. In order to determine the viability of potential LFC® plants, five detailed commercial feasibility studies—two Indonesian, one Russian, and two U.S. projects—have been completed. Permitting of a 15,000 metric-ton/day commercial plant in Wyoming is nearly complete.
Commercial-Scale Demonstration of the Liquid Phase Methanol (LPMEOH™) Process (Air Products Liquid Phase Conversion Company, L.P.)	No sales reported. Nominal 80,000 gallon/day methanol production being used by Eastman Chemical Company.
Advanced Coal Conversion Process Demonstration (Western SynCoal LLC)	No sales reported. Total sales of SynCoal® product exceed 1.5 million tons. Six long-term agreements are in place to purchase the product. One domestic and five international projects have been investigated. Western SynCoal LLC has a joint marketing agreement with Ube Industries of Japan providing Ube non-exclusive marketing rights outside of the United States. Ube is pursuing several projects in Asia. Western SynCoal is also discussing a potential marketing and development agreement with a U.S. engineering firm.

Exhibit 4-6

Commercial Successes—Industrial Applications

Project	Commercial Use
Cement Kiln Flue Gas Recovery Scrubber (Passamaquoddy Tribe)	No sales reported. The scrubber became a permanent part of the cement plant at the end of the demonstration. A feasibility study has been completed for a Taiwanese cement plant.
Blast Furnace Granular-Coal Injection System Demonstration Project (Bethlehem Steel Corporation)	Domestic sale. British Steel's Blast Furnace Granular-Coal Injection System was sold and installed on a facility owned by United States Steel Corporation.
Advanced Cyclone Combustor with Internal Sulfur, Nitrogen, and Ash Control (Coal Tech Corporation)	No sales reported. While the combustor is not yet fully ready for sale with commercial guarantees, it is believed to have commercial potential. Follow-on work to the CCT Program demonstration was undertaken, which has brought the technology close to commercial introduction.

Exhibit 4-7 Award-Winning CCT Projects

Project and Participant	Award
Full-Scale Demonstration of Low-NO _x Cell Burner Retrofit (The Babcock & Wilcox Company)	1994 R&D 100 Award presented by <i>R&D</i> magazine to the U.S. Department of Energy for development of the low-NO _x cell burner.
Evaluation of Gas Reburning and Low-NO _x Burners on a Wall-Fired Boiler; Enhancing the Use of Coals by Gas Reburning and Sorbent Injection (Energy and Environmental Research Corporation)	1997 J. Deanne Sensenbaugh Award presented by the Air and Waste Management Association to the U.S. Department of Energy, Gas Research Institute, and U.S. Environmental Protection Agency for the development and commercialization of gas-reburning technology.
Advanced Flue Gas Desulfurization Demonstration Project (Pure Air on the Lake, L.P.)	1993 Powerplant Award presented by <i>Power</i> magazine to Northern Indiana Public Service Company's Bailly Generating Station. 1992 Outstanding Engineering Achievement Award presented by the National Society of Professional Engineers.
Demonstration of Innovative Applications of Technology for the CT-121 FGD Process (Southern Company Services, Inc.)	1995 Design Award presented by the Society of Plastics Industries in recognition of the mist eliminator. 1994 Powerplant Award presented by <i>Power</i> magazine to Georgia Power's Plant Yates. Co-recipient was the U.S. Department of Energy. 1994 Outstanding Achievement Award presented by the Georgia Chapter of the Air and Waste Management Association. 1993 Environmental Award presented by the Georgia Chamber of Commerce.
Tidd PFBC Demonstration Project (The Ohio Power Company)	1992 National Energy Resource Organization award for demonstration of energy-efficient technology. 1991 Powerplant Award presented by <i>Power</i> magazine to American Electric Power Company's Tidd project. Co-recipient was The Babcock & Wilcox Company.
Tampa Electric Integrated Gasification Combined-Cycle Project (Tampa Electric Company)	1997 Powerplant Award presented by <i>Power</i> magazine to Tampa Electric's Polk Power Station. 1996 Association of Builders and Contractors Award presented to Tampa Electric for quality of construction. 1993 Ecological Society of America Corporate Award presented to Tampa Electric for its innovative siting process. 1993 Timer Powers Conflict Resolution Award presented to Tampa Electric by the state of Florida for the innovative siting process. 1991 Florida Audubon Society Corporate Award presented to Tampa Electric for the innovative siting process.
Wabash River Coal Gasification Repowering Project (Wabash River Coal Gasification Repowering Project Joint Venture)	1996 Powerplant Award presented by <i>Power</i> magazine to CInergy Corp./PSI Energy, Inc. 1996 Engineering Excellence Award presented to Sargent & Lundy upon winning the 1996 American Consulting Engineers Council competition.
Development of the Coal Quality Expert™ (ABB Combustion Engineering, Inc. and CQ Inc.)	In 1996 recognized by then Secretary of Energy Hazel O'Leary and EPRI President Richard Balzhiser as the best of nine DOE/EPRI cost-shared utility R&D projects under the Sustainable Electric Partnership Program.

- Providing forums and opportunities for feedback on program direction and information requirements.

Information Sources

A portfolio of publications and information access media exist and are being improved upon as program and marketplace events unfold. Information is currently distributed to over 4,000 customers and stakeholders, 275 of which are CCT project participants. The following provides a brief synopsis of the publications and information transfer mechanisms currently in place:

Clean Coal Technology Demonstration Program: Program Update provides an annual summary of program and project progress, accomplishments, and financial status along with an historical backdrop and program role relative to current policy.

Clean Coal Technology Demonstration Program: Project Fact Sheets provides a mid-year update on each project.

Clean Coal Technology Conference Proceedings serves as an update on issues impacting the program, feedback on program information requirements, and a periodic snapshot of how each of the active projects is progressing with some degree of technical depth.

Clean Coal Today newsletter offers the readership a quarterly look at the program, highlighting key events, updating project status, reporting on related issues, and listing the latest publications and upcoming events.

Project Performance Summary documents provide a 12-page synopsis of completed projects, highlighting operational, environmental, and economic performance.

Clean Coal Technology Topical Reports capture projects at critical junctures and highlight particular

technological advantages, project plans, and expected outcomes.

National Technical Information Service (NTIS) serves as the federal government's central source for the sale of scientific, technical, engineering, and related business information produced by or for the U.S. government. NTIS has most of CCT Program technical reports.

CCT Program Bibliography of Publications, Papers, and Presentations periodically updates the key materials available on the technologies demonstrated under the CCT Program.

The Investment Pays Off periodically takes a market-based view of the success of the CCT Program by virtue of commercial sales and relevance of ongoing activities to projected market need.

CCT Program—Lessons Learned documents the lessons learned in soliciting, selecting, and awarding projects and implementing the program.

CCT Compendium provides an electronic database incorporating the CCT Program publications that can be accessed on the Internet (<http://www.lanl.gov/projects/cctc/>).

Exhibits provide a means through graphics, photos, broadcast videos, and interactive videos to convey program messages at a variety of forums, and serve as focal points for distribution of literature and discussion of the program and information needs. There are currently four exhibits of varying sizes and complexity that are updated and modified, as necessary, to convey the appropriate message for specific forums.

Fossil Energy Home Page provides the primary Internet gateway to extensive information on DOE's Fossil Energy Program and to relevant World Wide Web links (<http://www.fe.doe.gov>).

Exhibit 4-8 summarizes how the above publications can be obtained and information sources can be accessed.



▲ The CCT Compendium is a new source of information on the CCT Program

Publications Issued in FY1999

The following publications were issued in fiscal year 1999 by the CCT Program. Similar publications can be expected in fiscal year 2000.

- *Seventh Clean Coal Technology Conference—21st Century Coal Utilization: Prospects for Economic Viability, Global Prosperity, and a Cleaner Environment, Volume 1 Policy Paper, and Volume 2 Technical Papers*
- *Clean Coal Technology Demonstration Program: Program Update 1998*
- *Clean Coal Technology Demonstration Program: Project Fact Sheets 1999*
- *Clean Coal Today: Winter 1998, Spring 1999, Summer 1999, Fall 1999*
- *Clean Coal Today Index*
- *Project Performance Summary—10-MWe Demonstration of Gas Suspension Absorption*

- *Project Performance Summary—180-MWe Demonstration of Advanced Tangentially-Fired Combustion Techniques for the Reduction of NO_x Emissions*
- *Project Performance Summary—ABB Environmental Systems SNOX™ Flue Gas Cleaning Demonstration Project*
- *Project Performance Summary—Advanced Flue Gas Desulfurization Demonstration Project*
- *Project Performance Summary—Cement Kiln Flue Gas Recovery Scrubber™*
- *Project Performance Summary—Demonstration of Coal Reburning for Cyclone Boiler NO_x Control*
- *Project Performance Summary—Full-Scale Demonstration of Low-NO_x Cell Burner® Retrofit*

- *Project Performance Summary—Nucla ACFB Demonstration Project*
- *Project Performance Summary—SO_x-NO_x-Rox Box™ Flue Gas Cleanup Demonstration Project*
- *Project Performance Summary—Tidd PFBC Demonstration Project*
- *Topical Report—Advanced Technologies for the Control of Sulfur Dioxide Emissions from Coal-Fired Boilers*
- *Topical Report—Commercial-Scale Demonstration of the Liquid Phase Methanol (LPMEOH™) Process*
- *Topical Report—Reburning Technologies for the Control of Nitrogen Oxides from Coal-Fired Boilers*

- *Topical Report—Technologies for the Combined control of Sulfur Dioxide and Nitrogen Oxides Emissions from Coal-Fired Boilers*

Information Access

The Department of Energy continued to expand its website to provide information on federal fossil energy programs and serve as a gateway to other related information throughout the United States and the world. Once into the DOE website, users can obtain general information and follow links to increasingly detailed information, ultimately accessing specific data on individual projects and facilities. Hyperlinks allow users to move seamlessly between headquarters and field sites. Users can also access technical abstracts and reports maintained by DOE's Office of Scientific and Technical Information at Oak Ridge, Tennessee. The gateways link to more than a hundred energy-related websites operated by private companies, trade associations, and other agencies worldwide.

Furthermore, the Fossil Energy International Activities site on the World Wide Web has been expanded with the addition of new country pages in the Western Hemisphere region (Dominican Republic, El Salvador, and Haiti). Many of the existing country pages have also been upgraded, with new hyperlinks to business- or energy-related information sources. An innovation at the Fossil Energy International Activities website is a series of newly created Country Energy Overviews. Each overview, individualized for a particular country, includes a status summary of that country's energy infrastructure, energy and environmental policies, and privatization efforts. Fifteen country pages are now available. The Uniform Resource Locator (URL) for the Fossil Energy International main page is <http://www.fe.doe.gov/international>

Exhibit 4-8 How to Obtain Updated CCT Program Information

Media	Description and Action
<i>Clean Coal Today</i>	Subscription to quarterly newsletter—Send name and address to U.S. Department of Energy, FE-24, Washington, DC 20585.
<i>Fossil Energy Home Page</i>	Primary gateway to extensive information on DOE's Fossil Energy Program and to relevant Web links—On the Internet, access http://www.fe.doe.gov and use menu and/or search options.
<i>CCT Compendium</i>	On the Internet, access http://www.lanl.gov/projects/cctc/ .
<i>CCT Program Update</i> and other publications	Send name and address to U.S. Department of Energy, FE-20, Washington, DC 20585.
<i>National Technical Information Service (NTIS)</i>	U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

and can be accessed via the “International” hyperlink in the Fossil Energy Home Page (<http://www.fe.doe.gov>).

In February 1998, DOE established a new information resource on the Internet. The Clean Coal Technology Compendium, sponsored by the Office of Fossil Energy and the National Energy Technology Laboratory (NETL), is dedicated to making the maximum use of information derived from the CCT Program. The compendium is designed to emphasize ease of use, and contains a broad collection of different types of data and information, making it applicable to the needs of both managers and engineers. For example, one can access the latest *Clean Coal Technology Demonstration Program: Program Update* and *Topical Reports* published periodically on individual CCT projects. The CCT Compendium is accessible via the Internet at <http://www.lanl.gov/projects/ctc/>.

Information Dissemination and Feedback

A number of mechanisms are used to disseminate program information to customers and stakeholders and obtain feedback from them on specific issues, program direction, and information requirements. The following provides a brief outline of the mechanisms.

Public Meetings were routinely held over the course of the acquisition phase of the CCT Program to solicit input on procurement actions. Subsequently, project participants have been holding open houses for the public, providing tours of demonstration facilities, and publicizing projects through groundbreaking and dedication ceremonies.

Executive Seminars involve program officials meeting with key industry officials at their places of business to facilitate discussion. Discussions seek to obtain a better understanding of the dynamics of the decision making process for adopting new power

generating technologies, determine how the program could best support the process and achieve a positive outcome, and gain insights on the future direction of the power industry. Over 50 meetings have been held since 1992 with influential leaders in the utility, independent power, regulatory, and financial communities.

Stakeholder Meetings bring together key stakeholder organizations for the purpose of coordinating programs, where appropriate, and discussing pertinent issues and implementation strategies to address the issues and outreach needs. Such stakeholder organizations include the Electric Power Research Institute (EPRI), Gas Research Institute (GRI), Coal Utilization Research Council, Center for Energy & Economic Development (CEED), Council of Industrial Boiler Owners (CIBO), Clean Coal Technology Coalition, and National Mining Association (NMA).

Conferences and Workshops bring together targeted audiences to review and discuss topics of interest, document discussions and findings, and provide recommendations, as appropriate. *Trade Missions* are a subset of these and differ only in that the thrust is international in character with the purpose of promoting the export of U.S. services and technology. The outreach program has participated in over 200 technical conferences, workshops, and trade missions since 1991.

Seventh Clean Coal Technology Conference

On June 21–24, 1999, over 230 people from 12 countries gathered in Knoxville, Tennessee for the Seventh Clean Coal Technology Conference. Cosponsors included CEED, NMA, EPRI, CIBO, and DOE. Air Products and Chemicals, Inc. and the Eastman Chemical Company hosted the conference and a site visit to the Commercial-Scale Demonstration of the Liquid

Phase Methanol Process being demonstrated at the Eastman Chemical Company facility in Kingsport, Tennessee. The following is a summary of the papers and presentations at the conference. The views of the various speakers do not necessarily reflect the views of DOE.

Opening Remarks. The DOE Assistant Secretary for Fossil Energy provided opening remarks, reflecting on how far coal technologies have come and on the promise for the future. The Assistant Secretary noted that progress in power system technology has far surpassed projections made in the 1970s, when only magnetohydrodynamics was expected to approach 50 percent efficiency. Now gasification, fluidized-bed combustion, and advanced gas turbine technologies provide a clear path to the 50 percent efficiency threshold. Moreover, only 20 years ago environmental control was more art than science. Through the CCT Program, advances in science-based gas cleanup technology have saved more than \$40 billion in compliance costs.

In looking to the future, the Assistant Secretary shared his vision of virtually pollution-free coal-based power systems, producing multiple products at 60 percent generating efficiency and reaching 85 percent thermal efficiency. He reflected on the fact that this vision approached that of the first Assistant Secretary for Fossil Energy over 20 years ago—“the day pollution would no longer be associated with the word coal.”

Keynote Speakers. Keynote speakers from both the coal industry and the utility industry addressed the conference participants.

Coal Industry Perspective. The coal industry, as represented by the President of NMA, perceives the challenge for the power industry as maintaining low

costs and reliability of service in meeting the projected 1.7 trillion kilowatt-hour of new electric power capacity needed by 2020 (almost twice the growth of the last 20 years). To meet this challenge, the coal industry supports programs such as DOE's CCT Program, Vision 21, and Industries of the Future. These programs are seen as providing coal and power producers the means to adequately perform. NMA views performance as the key to countering public policy unfavorable to coal. For example, coal provided the needed response to the last major energy build-up between 1982 and now (885 billion kilowatt-hours), this despite predictions of coal's demise and a nuclear power takeover of electricity generation. As a result, the United States has far lower energy costs than other industrialized nations, which American households have come to expect and American industry relies on for competitiveness. The suggested lessons to be learned are that fuel diversity must be maintained to adjust to changing circumstances and that performance determines outcomes.

▼ One of four clean coal technology exhibits, shown here, was used at the Seventh CCT Conference to convey a technical message.



▲ Seventh CCT Conference attendees toured the LPMEOH™ demonstration project.

Utility Perspective. The Chairman and President of American Electric Power (AEP) suggested that there are three givens regarding the future of coal in electricity generation: (1) powering the future will require a diversified fuel mix; (2) coal will continue in a prominent role in that mix; and (3) the advancement of clean coal and related technologies will be more critical than ever in going forward. There also is a need to change the public perception of coal, including speaking on the issues affecting coal, including: (1) air quality issues of urban and regional smog, or ozone, associated with nitrogen oxide emissions; (2) fine particulates, acid rain, mercury, and regional haze, primarily associated with sulfur dioxide emissions; and (3) the climate change questions of greenhouse gases, principally carbon dioxide, and global warming.

AEP sees the need to deflect environmental concerns with a technological response to preserve coal as the primary source for electric power generation, but

also recognizes the need to protect all other options as well. This includes continuing development of renewable energy sources, expanding use of natural gas, and keeping the nuclear option open. The AEP speaker noted that nuclear generation has ceased to be a source for new capacity, with no new plants having been ordered since 1973 (that weren't canceled).

Preserving the existing 100 nuclear plants is seen as a challenge. Further observations were that many hydroelectric plants may not be relicensed; despite support by utilities, renewables cannot begin to replace fossil fuels; and natural gas can not take the strain of replacing nuclear and coal generating capacity. The message conveyed was that fuel diversity is essential to preserving our nation's security and economic stability, which could be compromised if the public's negative perception of coal leads to public policy limiting coal use.

Issues. The issues identified at the conference include: (1) Deploying Clean Coal Technologies; (2) Global Community Responsibility—Role of Technology and Project Developers, Financiers, Consumers, and Governments; and (3) Coal in Tomorrow's Energy Fleet—Pressures and Responsibilities.

Deploying Clean Coal Technologies. For both developed and developing countries, coal is projected to be a key component in the energy supplies. However, current coal technologies can not satisfy the energy security and environmental goals of society and deliver affordable energy. On the other hand, power system technologies emerging from the CCT Program offer the economic, environmental, and operational performance potential needed to maintain coal in the fuel supply, meet environmental goals, and keep energy affordable. The challenge is in achieving widespread deployment of these clean coal technologies.



▲ The CCT Conference gives stakeholders the opportunity to offer feedback to CCT Program management.

The President's Council of Advisors on Science and Technology (PCAST) identified deficiencies in the process of moving technologies from the demonstration phase to widespread deployment. So despite successful demonstrations under the CCT Program, work remains to move the technologies into the marketplace. PCAST suggests that a "buydown" phase must ensue during which the incremental cost between the new technology and conventional technology is covered. During this buydown phase, cost and risk are reduced, as the technology is replicated and design and manufacturing methods are refined and standardized. PCAST concluded that a public entity is required to provide the policy and financial support for the buydown.

The status of clean coal technologies vis-a-vis the need for buydown was examined. Clean coal technologies currently have efficiencies higher than conventional pulverized coal units but lower than natural gas combined-cycle units. Clean coal technology capital costs, upon technology maturity, will be 20 to 25 percent lower than pulverized coal, but 50 percent higher than natural gas combined-cycle. Integrated gasification combined-cycle and pressurized fluidized-

bed combustion technologies are cost-competitive with pulverized coal now, but not natural gas combined-cycle. The IGCC and PFBC technologies could be competitive with natural gas combined-cycle in 2010, if fuel prices follow projected trends. The fuel price differential between coal and natural gas must be greater than \$2.00/10⁶ Btu for clean coal technologies to be competitive with natural gas combined-cycle.

Barriers identified for coal technologies by developers include capital cost, restructuring of the electric utility industry, and construction lead time. The capital risk of clean coal technologies is estimated at twice that of natural gas combined-cycle, which also means higher taxes, insurance, and financing costs. The electric utility industry favors less capital-intensive projects to maximize short term profits. Longer construction schedules for coal plants means slower response to market signals for new capacity and greater risk from more stringent environmental regulations.

From an environmental perspective, clean coal technologies provide high levels of pollution control and efficiency, but still fall short of a natural gas combined-cycle plant. Carbon sequestration represents a leveling factor for clean coal technologies in carbon control, but much work remains to be done.

Achieving widespread clean coal technology deployment and the benefits derived from having fuel diversity will require financial support for the developer. The preferred financial mechanisms identified were incentives, rather than grants or subsidies. Moreover, incentives must address higher capital costs, higher operating cost and risk, and start-up risk. These risks can be addressed by investment tax credits, production tax credits, and risk pools, respectively. A further stipulation was that such an incentives program would qualify technologies on the basis of increased efficiency over time and would be limited in scope and duration.

Global Community Responsibility—Role of Technology and Project Developers, Financiers, Consumers, and Governments. Speakers on this subject suggested that there is a global community responsibility to put energy resources and the advanced technology needed to use those resources in the hands of the two billion people in the world who currently lack access to these basic building blocks of modern society. Furthermore, by applying advanced technology, the global energy resources are more than sufficient to support economic growth without compromising the environment.

Speakers observed that little progress has been made in addressing the one-third of the six billion world population lacking access to commercial forms of energy. Most of these people live in developing countries where 90 percent of the population growth is occurring, and will increase by another two billion people by 2020. This will contribute to an estimated 50 percent increase in global energy consumption over the next two decades. New partnerships and economic models are needed to address the problem, such as:

- Restructuring and commercialization of energy enterprises;
- Sharing information through energy partnerships;
- Establishing transparent regulatory, pricing, and procurement policies;
- Investing in technology development reflecting a long-term, global view; and
- Providing tools for developing countries to solve their own problems.

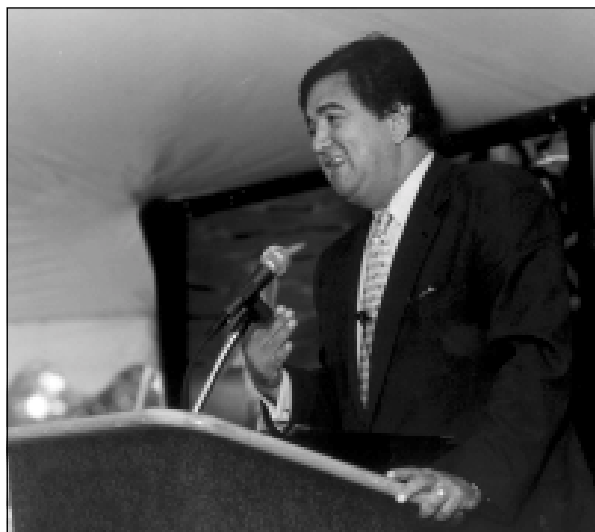
Coal must play a role in meeting energy demands because coal is the predominant indigenous resource for many of the developing economies. But bringing in

advanced coal technology faces the hurdles of least cost, risk averse decision makers, the “NIMBY” (not in my back yard) syndrome, and unrealistic expectations for renewables.

Speakers pointed out that developing countries will realize a 290 percent growth in energy requirement relative to 1990. The associated financial requirement is an estimated \$5 trillion, which developing countries can not meet along with other infrastructure needs. Strong recommendations were made by several speakers that industrialized countries share their prosperity in targeted efforts to bring energy to rural impoverished regions of the world. If not, poverty will continue for two billion people today and possibly four billion people by 2020 (half the projected world population).

The World Bank Group has adopted a number of policies to help bring modern forms of energy to the two billion people who currently do not have access.

▼ The Secretary of Energy addresses conference attendees and takes questions from the audience.



These policies include insisting upon reforms in the energy sector to support competition, private sector investment, and sound regulation of the sector. Policies also promote energy efficiency both on the supply- and demand-side and integrate energy pricing and environmental policies. The World Bank Group will undertake upstream “Energy-Environmental Reviews” to set priorities for action across the whole energy chain. For coal, the World Bank launched the Clean Coal Initiative, which addresses the entire coal chain from mining to end-use, and in parallel, seeks sector reforms and least-cost environmental control options.

The view from the commercial debt financing market, as presented at the conference, does not look promising for new coal technologies. The debt financing market does not see its role as accepting the risk associated with new technologies. Corporate entities or governments are expected to shoulder the risk until such time as the technology reaches commercial maturity. Furthermore, computer models used by power rate consultants include the choice of building a coal plant instead of a natural gas plant to supply future capacity needs. These computer models invariably choose natural gas plants because of lower capital cost and permitting ease. The operating assumption is, therefore, that new generation over the next 15 to 25 years will be supplied overwhelmingly by simple-cycle or combined-cycle natural gas-fired plants.

Coal in Tomorrow's Energy Fleet—Pressures and Responsibilities. According to views expressed at the conference on this issue, the energy business is changing. In this new energy business environment, research and development is not considered one of the factors driving corporate growth and value. The energy trading and marketing function will drive actions in the energy business. Traders primarily think in financial and

commodity market terms. This includes conducting daily assessments of “value at risk” and viewing generating assets as “real options.”

The growing use of options analysis for corporate decision making, or real options, represents a decision making revolution, according to *Business Week*. Research and development investments and technologies are considered real options because investment today can generate the possibility of new opportunities tomorrow. Also, technologies such as clean non-natural gas fossil fuel systems are options that can hedge against price risk and price volatility. For example, a plant that could produce syngas from coal (or other low-cost fuel) at an “out-of-the-money” price of \$4.00/10⁶ Btu, theoretically has value today as a hedge against natural gas exposure. Indicative values might be \$500–750/kW based on selling forward 15 years and the degree of price volatility. The question then becomes whether the syngas plant can be built for \$500–750/kWe.

From a real options perspective, “high tech” may not have as much option value as “low tech,” and integrated systems may lose option value versus non-integrated systems. “Enabling technologies” with the highest market value are those that allow rapid installation, are not location sensitive, and are deployed in a modular fashion.

The Department of Energy presented its view of tomorrow's energy fleet, which is embodied in the agency's Vision 21 Program. Vision 21 is a government/industry/academia cost-shared partnership to develop the technology basis for integrated energy plants that will result in the deployment of ultra-clean plants that produce electricity and “opportunity” products. Opportunity products could include clean liquid transportation fuels, steam, high-value chemicals,

synthesis gas, and hydrogen. Fuels include coal and natural gas in combination with other resources such as biomass, municipal waste, and petroleum coke. Vision 21 goals are to effectively remove environmental constraints as an issue for fossil fuel use by reducing pollutant emissions to near-zero, increasing efficiency to reduce greenhouse gas emissions by up to 50 percent, and enabling sequestration to achieve net zero CO₂ emissions.

Specific efficiency targets cited were 60 percent (HHV) for coal-based systems, 75 percent (LHV) for natural gas-based systems, 85 percent efficiency (HHV) in combined heat and power applications, and 75 percent fuels utilization efficiency in fuels production. To achieve these targets, enabling technologies have been identified that provide the foundation for the subsystems, or modules, that form the building blocks of a Vision 21 plant. These enabling technologies include: oxygen and hydrogen separation membranes, high-temperature heat exchangers, fuel flexible gasification, hot gas cleanup, advanced combustion, fuel flexible turbines, fuel cells, and advanced catalysts. Supporting technologies that crosscut enabling technology efforts include: materials, advanced computational modeling (virtual demonstration), advanced controls and sensors, advanced environmental controls, and advanced manufacturing and modularization.

A number of system examples, such as a gasification/gas turbine/fuel cell hybrid cycle, were presented to illustrate that efficiency targets were feasible. The Department of Energy representative pointed out that, in the evolution of these systems, there will be spinoff technologies commercialized. The sequential commercialization and integration of technologies will mitigate the risk and cost of module development.

Industry representatives identified several targets for coal-based generation technologies by 2020 along with several cross-cutting enabling technologies. The targets are capital costs of \$800/kW, efficiencies of 50-60 percent, SO₂ removal of 99 percent, NO_x emissions of 0.05 lb/10⁶ Btu, and 100 percent waste utilization. The enabling technologies are high temperature/high pressure filters, advanced combustion turbines, high temperature steam cycle materials, and hazardous air pollutant controls. With these capabilities, it is projected that coal can account for 20 percent of primary energy in a balanced 2050 portfolio.

Looking to the future, it was also pointed out that carbon capture and sequestration offer an opportunity to remove the single greatest concern over continued reliance on fossil fuels—global climate change. To scope the challenge, results were presented from detailed cost analyses on CO₂ capture followed by a discussion of the challenges involved in developing secure storage reservoirs.

In addressing CO₂ capture costs, analysts selected three representative power generation technologies: IGCC, natural gas combined-cycle, and pulverized coal-fired combustion. Analysis showed the incremental cost of electricity for CO₂ capture to be 1.1 to 1.7 cents/kWh for IGCC; 1.9 to 2.1 cents/kWh for natural gas combined-cycle; and 2.3 to 3.1 cents/kWh for pulverized coal. This suggests that coal-based IGCC could compete with natural gas in a greenhouse gas constrained world.

The CO₂ capture costs presented represent commercial technology today. The potential to reduce these costs is great, *e.g.*, improving thermal efficiency of the basic plant, or reducing the energy requirement for CO₂ capture by improving separation technologies. The sequestration options identified along with capaci-

ty estimates are listed below. For reference, the total annual worldwide anthropogenic carbon emissions are about 7 gigatons of carbon (Gtc).

Reservoir	Capacity (Gtc/yr)
Ocean	1,000s
Deep Saline Formations	100s to 1,000s
Oil & Gas Reservoirs	100s
Unminable Coal Seams	10s to 100s
Terrestrial Biosphere	10s to 100s
Utilization	0.1

Geologic sequestration issues identified include uncertainties in storage volumes available, long-term integrity of the storage, and costs of CO₂ transport and storage. Storage integrity is both a performance and public safety issue. Ocean sequestration issues include sequestration efficiency for the proposed methods and environmental impacts.

Conferences and Workshops Held in FY1999

Third Meeting of Energy Ministers from the Asia Pacific Economic Cooperation, and Sixth Annual Technical Seminar. In October 1998, the Energy Ministers from the Asia Pacific Economic Cooperation (APEC) held their third meeting in Okinawa, Japan to consider policy issues, many of which are important to vendors of clean coal technologies and other fossil energy technologies in foreign markets. The U.S. Secretary of Energy led the U.S. delegation. APEC was formed in 1989 to address issues of growing regional interdependence. Members include 18 countries bordering the Pacific Ocean with a combined Gross Domestic Product of \$13 trillion in 1995. Concurrent with the Ministers' meeting, the FE-led Experts Group on Clean Fossil Energy (part of the APEC's Energy Working Group (EWG)) hosted its *Sixth*

Annual Technical Seminar with a focus on practical coal, gas, and oil use technologies for developing economies.

Coal is of extreme importance to the Pacific Rim because of large indigenous supplies. In fact, an APEC-sponsored workshop in February 1998 in Honolulu, Hawaii, "Energy Security: Fuel Supplies for the Power Industry," concluded that coal would continue to play a significant role in the region's fuel mix. Natural gas was seen as desirable due to its environmental benefits and potential availability, while oil use in the region's power sector was not expected to grow.

Implications of the Asian financial crisis pervaded the October 1998 discussions. Ministers agreed that energy can play a key role in economic recovery. Investment in infrastructure, a key goal, could induce a multiplier effect. In spite of the economic downturn and projected slower growth in demand, the region's demand for energy is expected to outpace energy production by a wide margin. The Asia Pacific Energy Resource Centre, established by the EWG, presented the Ministers with a new forecast that predicts total primary energy demand in the region will increase 41 percent over the period 1995–2010. This growth will require large amounts of investment capital. To reduce dependence on imported oil, APEC nations are interested in diversifying energy supplies, developing financing for power infrastructure, and encouraging energy efficiency.

The Ministers who met at Okinawa endorsed a work program on environmentally sound infrastructure for all energy sources. Concerns are not only for environmentally sensitive siting, but maintenance practices and employee training. The goal of the work program is to provide an impetus to the application of predictable, transparent, and consistent energy policy practices.

Policy recommendations to accelerate investment in natural gas infrastructure (part of the Natural Gas Initiative launched at the first meeting of the Ministers in Edmonton, Canada) were also approved. Recommendations were included in the report, "Accelerating Investment in Natural Gas Supplies, Infrastructure and Trading Networks in the APEC Region." The Initiative stresses not only the building of pipelines, but addressing regulatory and cross-border issues that may act as impediments.

Reducing costs through cooperation in energy standards was another endorsement by the Ministers that has potential bearing on coal and the standards for equipment to be sold. APEC members' economies have been surveyed to determine the range of testing practices and procedures and the degree of mutual recognition of facility test results. The standards notification provision endorsed by the Ministers would increase transparency and consistency in energy efficient product standards within APEC. To improve energy efficiency, Ministers also endorsed a voluntary "pledge and review" system. Energy efficiency means not only "green" technologies, but better use of conventional fossil fuel resources.

Although APEC is an organization of government representatives, the Energy Ministers have directed the EWG to expeditiously engage with businesses on measures to improve investor confidence in APEC nations' energy sectors. The EWG has established a Business Network comprising two private sector energy executives from each member economy. The Ministers instructed the EWG to work with industry to implement the principles in the "APEC Manual of Best Practice Principles for IPPs," which was endorsed at Edmonton.

Trends in Development in Mining and Power Production From the Point of View of Future Applications of Clean Coal Technologies.

In November 1998, two FE representatives were invited to chair panels and present papers at the conference *Trends in Development in Mining and Power Production From the Point of View of Future Applications of Clean Coal Technologies*, held in Kocise, Slovakia. The conference was hosted by the Slovak Academy of Sciences Institute of Geotechnics (Slovak Academy), with broad sponsorship by the mining and power industry in Slovakia. The Office of Fossil Energy, under a Science and Technology grant from the U.S. Department of State, has collaborated with the Slovak Academy on research focusing on the region's high-ash, high-arsenic coals, specifically the process of cleaning the coal using the concept of triboelectrostatic charging. This process avoids expensive dewatering. Slovakian brown coal is currently used for power generation in pulverized coal plants with few environmental controls, and is also used extensively for district heating and rural home stoves. Coal supplies are dwindling and expected to last for only another 20 years.

The conference, attended by some 75 key representatives from the academic, mining, power, district heating, chemical, steel, and environmental sectors in Central and Eastern Europe, addressed various technical issues common to this area, particularly cost issues of environmental compliance and power production. Currently, 60 percent of Slovakia's power comes from older nuclear plants, 30 percent from coal plants, and 10 percent from natural gas. Slovakia is under pressure to shut down the Chernobyl-type nuclear plants and must find replacement capacity, or it will have to import electricity. There is hesitancy to become overly dependent on natural gas, and strong interest (including

employment in the mining sector) in continuing to use indigenous coal supplies while they last. In general, the country seeks a better balance between nuclear-, coal-, and natural gas-fired power plants.

Coal-fired plants in Slovakia are slowly being converted to circulating fluidized-bed combustion boilers. A definite market exists for cleaner coal technologies for district heating, small combined heat and power plants, and for chemical raw materials. Conference participants were most interested in the presentation on CCT projects, particularly the Nucla and JEA atmospheric fluidized-bed combustion projects, Piñon Pine IGCC, Liquid Phase Methanol, and granulated coal injection as demonstrated by the Bethlehem Steel project, because these technologies could have application throughout all of Central and Eastern Europe. In all, Slovakia and other countries in the region have been keenly watching coal R&D advances, and seek opportunities to deploy new technologies applicable to their reserves.

International Seminar on Combustion Technologies for Clean Energy Generation. In December 1998, representatives from FE participated in the *International Seminar on Combustion Technologies for Clean Energy Generation* held in Mexico City. This activity was part of the U.S.-Mexican Bilateral Agreement for Energy Cooperation, under the Hemisphere Energy Initiative's Clean Energy Working Group program. Mexican sponsors included the National Commission on Energy Savings (CONAE) and the Institute of Electric Research.

An important part of the seminar was FE's presentation entitled "Fluidized-Bed Combustion Repowering for Mexico," which was delivered to more than 100 Mexican energy officials. Presently, 60–70 percent of Mexico's power is generated from fossil fuels, 80–90

percent of which comes from oil, with the rest generated from natural gas and two pulverized-coal plants that burn high-ash (approximately 50 percent ash) Mexican coal. A new coal plant being built will run on imported, low-sulfur coal. Approximately 17 percent of Mexico's power is generated by hydroelectric plants and the remaining national demand is met by two 650-MW nuclear units, supplemented by some geothermal, wind, and solar units.

The presentation focused on four fluidized-bed combustion (FBC) repowering options for Mexico's aging oil-fired power boilers. These options included (1) replacement of existing units with atmospheric fluidized-bed boilers, (2) conversion of existing units into fluidized-bed boilers using compact separator designs, and replacement of existing boilers with either (3) first generation PFBC or (4) second generation (topped) PFBC units. The fuel flexibility of FBC was stressed. Particular attention was devoted to petroleum coke in recognition of Mexico's global position as a major oil producing nation. The audience asked a number of questions concerning burning of petroleum coke in the United States. Examples such as the NIBSCO 300-MW petroleum coke-fired plant in Lake Charles, Louisiana were discussed. The NIBSCO plant is completing its sixth year of successful operation, which includes the sale of all produced ash by-product for use in highway construction.

The Office of Fossil Energy's final technical presentation was on the Vision 21 program. Audience questions focused on the continuing use of fossil fuels, especially coal, into the next millennium. The Mexican audience was surprised to see that such focused and



▲ Representatives from the U.S. DOE participated in the "International Seminar on Combustion Technologies for Clean Energy Generation," held in Mexico City in December 1998.

careful attention is still being given to fossil-based power technologies. The FE presenter indicated that, with the exception of nuclear, which is politically not an option in many countries, fossil is the only viable energy source to meet the bulk of the world's demand for power. The presenter stressed the need to develop and deploy technologies that will allow use of fossil fuels as cleanly and efficiently as possible.

On December 4, 1998, a follow-up meeting was held at the offices of Mexico's Secretariat of Energy, which generated further questions about FBC operations. CONAE indicated that it would take the lead to promote future FBC activities between FE and Mexico.

13th Annual U.S./Japan Joint Technical Workshop on Coal Technology. A successful 13th Annual U.S./Japan Joint Technical Workshop on Coal Technology was held in early March 1999 at the Rocky Gap Lodge near Cumberland, Maryland. Sixty-six workshop participants exchanged R&D project information relating to advanced clean coal technologies, coal liquefaction, liquefaction materials, and surface gasification. Japan has recently been pursuing coal utilization R&D quite aggressively, and has been involved in direct liquefaction research.

The Director of the National Energy Technology Laboratory (NETL), who is also Co-Chair of the U.S.-Japan Coordinating Committee on Coal Energy R&D, spoke on the globalization and deregulation forces behind energy supply decisions, and summarized FE's current R&D focus. The NETL Director led a U.S. team of government representatives, members of research organizations, and the private sector. The representative of the Japanese Ministry of International Trade and Industry (MITI), and Co-Chair of the committee, led a Japanese delegation of 24 scientists and engineers from utilities, research organizations, industry associations, and energy companies.

The technical exchange was open and frank. A representative of MITI's Agency of Natural Resources and Energy, spoke on Japanese coal utilization policy, noting that Japan imports 80 percent of its total energy feedstock and 99.7 percent of its oil (with oil accounting for 54 percent of Japan's total energy consumption). Japan is the second largest foreign consumer of U.S. coal. Only five percent of coal used in Japan is domestic. Other industrialized nations (e.g., Germany, France, and Italy) import over 95 percent of their oil. The U.S. depends on imports for 20 percent of its total energy and 50.7 percent of its oil, with oil comprising 38 percent of total U.S. energy consumption.

Workshop participants noted that ample, low cost, stable coal supplies worldwide support a measure of diversification and economic safety for both industrialized and developing countries, making the development of clean, efficient, coal utilization technologies an imperative for the future. DOE presentations introduced the Vision 21 research program the Department has proposed for coal-based power and fuel systems in the next century. McDermott International, Inc. summarized low-NO_x burners, as well as emissions control studies for particulate matter and trace elements. The



▲ NETL Director addresses attendees at 13th Annual U.S./Japan Joint Technical Workshop on Coal Technology.

Energy & Environmental Research Center described an advanced hybrid particulate collector, American Electric Power gave a presentation on the 600-MWe demonstration of selective non-catalytic reduction to be conducted at its Cardinal Unit 1, and Air Products & Chemicals presented an overview of advanced integration concepts for oxygen plants and gas turbines in gasification/IGCC facilities using ion transport membranes.

Japan's New Energy Development Organization described the EAGLE (Energy Application for Gas, Liquids, and Electricity) integrated coal gasification, molten carbonate fuel cell combined-cycle plant that is moving toward pilot-scale demonstration in the 2000 to 2002 time frame. About 90 percent of the project is funded by the Japanese government. Japan's Electric Power Development Company presented recent results from the 71-MWe Wakamatsu PFBC plant, as well as from recent PDU testing of an advanced PFBC process. Representatives from Tokyo Electric discussed results obtained from a 200 ton/day IGCC pilot plant at Nakoso, using a process design by Mitsubishi Heavy Industries.

Following the workshop, representatives from the Japanese delegation toured NETL in-house laboratory facilities and the Tampa Electric IGCC project.

Prospects for Cleaner Fossil Fuels Systems in Sustainable Development: Communicating Their Strategic Value in the Euro-Asian Region. The U.S. Department of Energy was among the sponsors of the highly successful conference, *Prospects for Cleaner Fossil Fuels Systems in Sustainable Development: Communicating Their Strategic Value in the Euro-Asian Region*, held in Ankara, Turkey in May 1999. Other conference sponsors included the World Energy Council (WEC), as well as the WEC Turkish National Committee and the Regional Working Group for Cooperation in the Field of Energy, the U.S. Agency for International Development (USAID), and the U.S. Energy Association.

The highlight of the conference was an appearance by the President of Turkey. In his remarks, the Turkish President emphasized the role of Turkey as a major energy distribution point as well as energy consumer. Turkey's average energy demand is predicted to grow 8–10 percent per year through 2010. A \$280 billion investment program is planned for the energy sector over the next 30 years. While the most timely energy issue is planned commencement of the Baku-Ceyhan oil pipeline and the Trans-Caspian natural gas pipeline, Turkish energy officials highlighted the importance of coal. Turkey has 8 billion tons of lignite (brown coal) reserves as well as some "hard" coal. Sixty percent of coal produced is used for generating electricity, with the remainder going for industry and household use. By 2020, lignite and hard coal are expected to represent 20 percent of installed capacity.

DOE's Office of Fossil Energy showed a strong presence at the conference, with the FE Assistant

Secretary as the Keynote Speaker, the Director of the Office of Import & Export (within the Office of Coal and Power Systems (OC&PS)) serving as President of the first day's session, and the Director of the Office of Power Systems (within OC&PS) making a presentation on the role of fossil energy and Vision 21. The Assistant Secretary spoke of technology as a link between a more prosperous economic future and a cleaner environment, and discussed the benefits of carbon sequestration.

The efficiency of power plants was discussed as well as the potential for public/private power partnerships. A spokesman for General Electric indicated that European IGCCs, fueled by coal as well as other fuels, are performing well, and he predicted a growth in IGCC over the next few years. Coal provides over 50 percent of electricity production in Germany, and 97 percent in Poland. For China and India, the figure is 70 percent.

Privatization was seen by conference participants to be of key importance. The World Energy Council sees market-oriented restructuring as a main condition to clean coal technology deployment. Such a restructuring may be able to surmount the barriers of poor coal quality.

Prior to the conference, the FE delegation and private sector representatives met with representatives of the Turkish energy sector who asked for U.S. technical advice in the privatization process. As a result of the meeting, FE will draft an Energy Science and Technology Agreement to formalize the effort. At the meeting, Turkish officials also expressed interest in U.S. mining technology and the possibility of information exchanges.



▲ The Director of FE's Office of Import and Export (middle) and the FE Assistant Secretary (right) address WEC conference attendees.

Trade Mission Activities in FY1999

China. In April 1999, the U.S.-China Energy and Environmental Technology Center (EETC) held its first annual Board of Directors meeting. At the meeting, held in Washington, D.C., the Board of Directors reviewed accomplishments over the past year, as well as new directions. EETC is funded jointly by DOE, U.S. Environmental Protection Agency and the Chinese State Science and Technology Commission. The U.S./China Institute has a cooperative agreement with U.S. DOE to manage and operate the EETC. Tulane and Tsinghua Universities, in turn, are subcontracted to run the day-to-day operations. EETC's mission is to enhance the competitiveness and adoption of U.S. clean and environmentally superior technologies in China by focusing on education and training, promoting the use and profitability of U.S. technology, and

supporting policy development in China to encourage the responsible use of coal.

Over the past year, the Hydrocarbon Technologies, Inc. (HTI) direct liquefaction project, proposed to be located near Shaanxi Province, has advanced from pre-feasibility to the feasibility study phase. EETC has acted to promote the project to the Chinese Government. Other liquefaction projects, sponsored by German and Japanese companies with financial support from their respective governments, are also contending for the ultimate award. A commercial plant using HTI technology could produce 50,000 barrels/day of gasoline and diesel fuel using 10,000-12,000 tons/day of bituminous coal. The pre-feasibility study established that the project can use a variety of Chinese coals. The feasibility study will include further testing as well as evaluation of economics and project financing. DOE has supported test runs on Chinese coals at a bench test unit.

The Chinese government appears ready to make a decision on another project, a 300-MW commercial IGCC project to be located in Yantai in the Shandong Province. Foreign investment is being sought. Construction is expected to start in 2000-2001. Since 1993, DOE and U.S. industry have been working closely with the Chinese government, industry, and R&D organizations to help China develop this first IGCC project.

EETC is also supporting the efforts of The Babcock & Wilcox Company (B&W) to secure an FGD joint venture from China's State Power Corporation, a government agency that has decided to increase the engineering and fabrication capacity of FGD systems throughout China. B&W was a co-sponsor with the EETC of the February 1998 *U.S.-China Workshop on SO_x Control Technology*.

In other areas, EETC has been sponsoring studies of upgrading coal-based fertilizer plants to become more energy efficient. EETC has helped the city of Chongqing convert its fertilizer plant to natural gas, but in most cases natural gas sources are not available. Finally, EETC will broaden its activities in climate change and CO₂ reduction, establishing a special task force and continuing work in coal gasification, coal washing, biomass gasification for distributed power, and ash utilization.

India. The Office of Fossil Energy, with funding from the USAID, and in conjunction with Tennessee Valley Authority (TVA) and EPRI, is preparing to support the efficiency improvement testing aimed at greenhouse gas reduction at the 210-MW Unit No. 7 of the Maharashtra State Electricity Board's coal-fired Koradi Power Plant in India.

In another effort, FE, along with USAID support, sent an electrostatic precipitator (ESP) specialist to India to determine the effectiveness of "sodium conditioning" on ESP performance, given the high ash loading conditions experienced at Indian coal-fired power plants. With a very simple test setup, approximately 0.25 percent by weight of sodium was added to the coal being fed to one of the four 67-MW units at a power plant in Korba, India. The results were outstanding. The normal stack particulate loading of 340 milligrams per standard cubic meter (a very dirty looking stack plume) was reduced to 60 milligrams per standard cubic meter, which is an essentially clean stack to the naked eye. The sodium material used is considered a waste product and the primary cost was shipping; thus the addition to the cost of electricity was less than one-half of one cent per kilowatt-hour.

Poland. Air quality in many Central European cities has degraded during the past several decades



▲ The Bilaspur Coal Washery Project in the state of Madhya Pradesh is India's first private commercial coal washery for electric power generation.

with heavy use of solid fuels for heating. Since 1990, the U.S. Department of Energy has been involved in a program aimed at reducing air pollution caused by small coal-fired sources in Krakow, Poland. Although the activity is focused on the city of Krakow, it is expected that the results will be applicable to the entire region. Formal basis for the U.S. assistance to Poland in this area was provided by the Support for Eastern European Democracy Act of 1989 (SEED). Part of this legislation directed that DOE cooperate with U.S. and Polish experts to undertake an assessment and implementation program in Poland to use fossil fuels cleanly in small-scale combustion equipment. Funding for this program has been provided to DOE by the USAID.

The SEED program was specifically directed toward the problems of low altitude emissions sources in Krakow. A city of 750,000 and Poland's capital from the 11th to 17th centuries, Krakow is a major university and industrial center, and contains numerous historic buildings. The city has been included in the United Nations Educational, Scientific and Cultural Organization (UNESCO) list of world cultural heritages. The program was designed to assess the total problem of low-level emission sources within the center of "Old Krakow" and progress to the outskirts;

identify specific large emission sources; determine cost-effective approaches for long-term remediation; and use a multi-faceted technical approach to implement new technologies. Air quality has improved dramatically since the program began. A number of major emitters have already had numerous thermal/burner/particulate control systems installed. The program is currently in its last phase, in which many particulate sources are being closed due to connection to an expanded district heating system, home stoves are having electric heating elements installed, and electrical upgrading is being implemented. United States funding provides new equipment, preferably through joint US-Polish suppliers, to a variety of city, regional, and private energy offices and partners. A significant upgrade to the large Polish American Children's Hospital is also underway—the only dedicated pediatric medical research facility in Poland.

A number of projects have evolved from the Krakow effort and have been implemented in other parts of Poland and Central Europe. Due to lower initial capital costs and operating costs, mechanical particulate collectors traditionally have been installed in industrial applications in Poland rather than more complex devices. One such device is the core separator developed by LSR Technologies, of Acton, Massachusetts. Original development work on the core separator was done under the DOE Small Business Innovative Research Program. Dust emissions from this device are typically 3–6 times lower than from the best cyclone collectors, and its performance approaches that of fabric filters and electrostatic precipitators, but at a much lower cost. Within Krakow, core separators were installed at a 6-MW stoker fired boiler in a motor manufacturing plant and at a 1.5-MW boiler located at the central bus service center. Particulate

removal at these sites averaged 94 percent. Another 52 core separators are either in operation or being installed within Poland and neighboring countries.

The total Krakow program continues to show marked improvement in air quality due to the many emission sources that are either being controlled or eliminated. Core separators alone are removing more than 575,000 metric tons per year of particulates in the region. Through 1998, it is estimated that more than 126,000 metric tons of CO₂ emissions per year have been eliminated; with new ongoing remediation projects, another 25,000 metric tons/year will be eliminated. Upgrading the large Children's Hospital complex alone will eliminate approximately 15,000 tons/year of CO₂, as well as closure of a large coal-fired dedicated (17.5 MW) boiler. Clearly, the joint U.S./Poland effort is having a positive environmental impact in the region.

Russia. During June 1999, a delegation from DOE's Office of Fossil Energy and Office of International Affairs visited Moscow, Russia for technology information exchange with Russian organizations concerned with coal, coal technology, and power production. Specific discussions were directed toward the use of clean and efficient coal technologies as a component of environmental protection, including (1) new technologies and equipment to improve combustion efficiency in thermal power plants and advanced gas turbines and gasification combined-cycle technologies; and (2) a common understanding of the present and future strategic value of fossil fuels for electric power and fuels production in Russia and in the U.S.

Russian organizations visited included: the Fossil Fuels Institute of the Ministry for Fuel and Energy of Russia; the All-Russian Thermal Engineering Institute; the Office of the Deputy Minister, Ministry of Fuel and

Energy of Russia; the Moscow Center for Energy Efficiency; and the Committee of Coal Industry of the Russian Federation. As a result of the visit, a number of areas for cooperation were identified that could be of potential mutual benefit. It was agreed that DOE would initiate preparation of a draft Annex under the existing bilateral Science and Technology Agreement, specific to the development and utilization of clean and efficient fossil fuels. The Annex will identify and institutionalize cooperation between the DOE and Russian counterpart governmental organizations.

Taiwan. Agreements are being prepared with Taiwan allowing FE to provide technical expertise, training, and scientific exchange activities in the areas of clean coal technology, coal utilization, and waste and by-product utilization. A major expected outcome includes FE technical support for an IGCC feasibility study. FE would advise Taiwan on project financing (a mix of Taiwan government and private funding), plant siting, and technology selection. The agreement would first be signed between FE and the Taipei Economic and Cultural Representative Office (TECRO), and then between the Energy Commission of the Ministry of Economic Affairs and the American Institute in Taiwan. After the agreements are finalized, both Taiwan and the United States hope to branch out into other cooperative work—fuel cell development, independent power production, rural electrification, computer modeling for energy policy decisions, environmental management, cement and steel factory cleanup, and paper mill waste treatment. Tulane University's U.S./China Institute has been active in coordinating and supporting FE efforts on these agreements.

FE began working a year and-a-half ago with Taiwan to promote adoption of clean coal technologies. Taiwan imports about 96 percent of its primary energy—mostly

oil, coal, and liquefied natural gas. The country seeks to develop a long-term energy policy and emissions control strategy, preferably regional in scope.

Ukraine. U.S. and Ukrainian participants met in April 1999 in Research Triangle Park, North Carolina to discuss progress to date on an EPA and DOE sponsored fuel reburning project in Ladyzhin, Ukraine. A multi-fuel reburn system (capable of using natural gas, coal, heavy fuel oil, or combinations thereof) is being installed to reduce NO_x emissions from Unit 6, a 300-MW wet-bottom coal-fired boiler at Ladyzhin Power Station, 200 miles south of Kiev. Under an interagency agreement, funding is provided by EPA's Environmental Technology Initiative. Technical guidance for process design and operation are provided jointly by EPA's National Risk Management Research Laboratory and FE.

The project follows an earlier collaborative effort in 1992 (in which DOE did not participate) where a natural gas reburning system was installed at Ladyzhin Power Station Unit 4. This operation reduced NO_x emissions by more than 50 percent. The success of this early demonstration encouraged the Ladyzhin Power Station and the Ukrainian Power Ministry to extend the application of this technology to other units. These units were needed to help meet pending regulations that will place a tax on all emissions. Fuel cost, availability, and distribution problems in Ladyzhin made a multi-fuel approach desirable.

In the reburn method, 5–20 percent of total boiler fuel is injected downstream of the main burners to create a fuel-rich zone, followed by injection of burn-out air, and can remove 50 percent or more of uncontrolled NO_x emissions. The technology is very promising for Ukraine and Russia, where 50 percent of all boilers are of a slagging or wet-bottom design, for

which conventional low-NO_x burners are not generally applicable.

Energy and Environmental Research Corporation of Irvine, California is supporting system design. Component design, fabrication, and installation are being done by Ladyzhin Power Station staff. To date, the plant has installed separate coal mills for supplying the reburn fuel and has conducted preliminary tests of the coal reburn system. Nitrogen oxides reductions of 25–35 percent have been achieved compared to operation without injection of reburning fuel, *i.e.*, using only the overfire air ports component of the reburning system. During operation with coal as the reburning fuel, this performance translates into total NO_x reductions of 50 percent. Additional system optimization is currently underway to improve the reburn coal feed rate and NO_x reduction capacity.

